

Appendix D

Magnetospheric Multi-Scale Mission

Instrument Specification

1 Instruments

1.1 Instrument Summary

While the instruments have not been selected for the MMS mission, the science definition team has suggested a candidate list of instruments. For the purposes of this study the list of instruments will be as shown in Tables 1 & 2.

Table 1

Parameter	Magnetometer and Search Coil	Hot plasma detector	Energetic Particles	Electric Field	Totals
Mass (kg) per unit	1.5	8.0	2.5	17.0	37 38.5 kg
Quantity	1 each	2	1	1	
Operation Power (W) per unit	1.2	7.0	2.0	15.0	32 233.4 watts
Data Rate (Normal) per unit	5 kbps	6 kbps	2 kbps	5 kbps	24 20 kbps
Data Rate (Burst)	5 kbps	32 kbps	2 kbps	65 kbps	104 109 kbps
FOV (deg)		10° x 360° (1)	10°x160°		
Size (cm)	18x10x8 (Elec. box) 5x5 (sensor)	20.3x20.3x25 (cylinder: instr & elec. Box)	11x11x10 (instr & elec. Box)	See section 1.4 & see figure 4	

(1) For non-scanning version of the instrument. See description of instrument.

Table 2

Parameter	IRAS
Mass (kg)	1.2kg electronics + 0.8kg antennas
Operation Power (W)	5 (avg), 15 (peak)
C&DH storage Rate	100bps
C&DH transfer rate	500bps
Size cm (LxWxH)	12 x 12 x 4

The Interspacecraft Ranging and Alarm System (IRAS) shall be considered a GFE'd instrument for the purposes of this document.

1.2 Hot Plasma Instrument

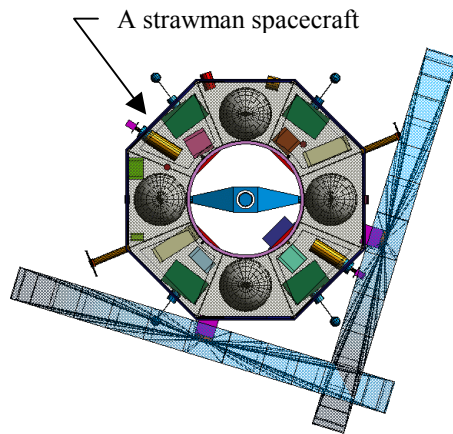


Figure 1, Non-scanning 20 rpm- Hot Plasma FOV

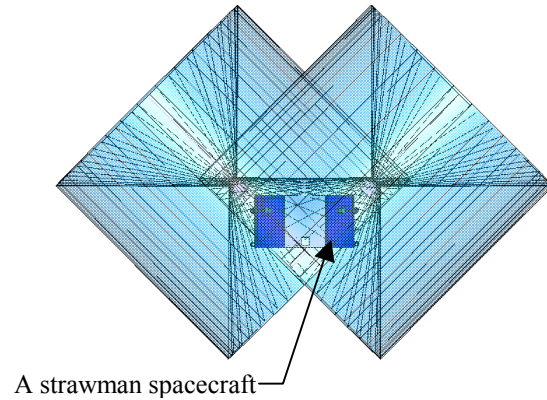


Figure 2, Scanning 6rpm – Hot Plasma FOV

The Hot Plasma instrument is used for measuring the number, density and energy for particles in the range of 1eV to 30eV. The instrument will have a geometry factor of $0.01 \text{ cm}^2\text{-sr-eV/eV}$ for ions and $0.005 \text{ cm}^2\text{-sr-eV/eV}$ for electrons, an energy resolution of 4 ($E/\Delta E$) and an absolute accuracy of 5-10% with a relative accuracy of 1% between spacecraft. The instrument can be built in one of two configurations: a non-scanning instrument with a field of view (FOV) of $10^\circ \times 360^\circ$ (shown in figure 1) and a scanning version with an instantaneous field of view of $10^\circ \times 360^\circ$ but the beam can scan $\pm 45^\circ$ (shown in figure 2). Note that the spacecraft shown is for illustrative purposes and is not meant to imply a preferred spacecraft configuration.

The two non-scanning instruments (per spacecraft) can provide 4π steradian coverage at 0.75seconds time resolution if they are mounted as shown in figure 1 ($\sim 90^\circ$ apart). The time resolution is inversely proportional to the spin rate. For slower spinning spacecraft, an electrostatically scanning instrument has been developed which can provide the time resolution independent of spin rate. To provide 4π steradian coverage, two of the scanning instruments are mounted at 180° to each other as shown in figure 2. In each case the instrument sensor body is approximately a cylinder 8inch diameter and 8inch long. Impingement into the Hot Plasma instrument FOVs by the wire booms of the electric field instrument is deemed acceptable.

The non-scanning instruments have been baselined for the MMS mission. In the event that the spacecraft is not capable of meeting the pointing requirements at 20rpm it is possible to use the non-scanning instrument at 6 rpm.

This instrument will require a constant high purity nitrogen purge from integration to launch. A purge port will be provided at the instrument interface.

It can be assumed that the instrument is capable of a Mil-Std-1553 or other high level interface.

1.3 Energetic Particle Instrument

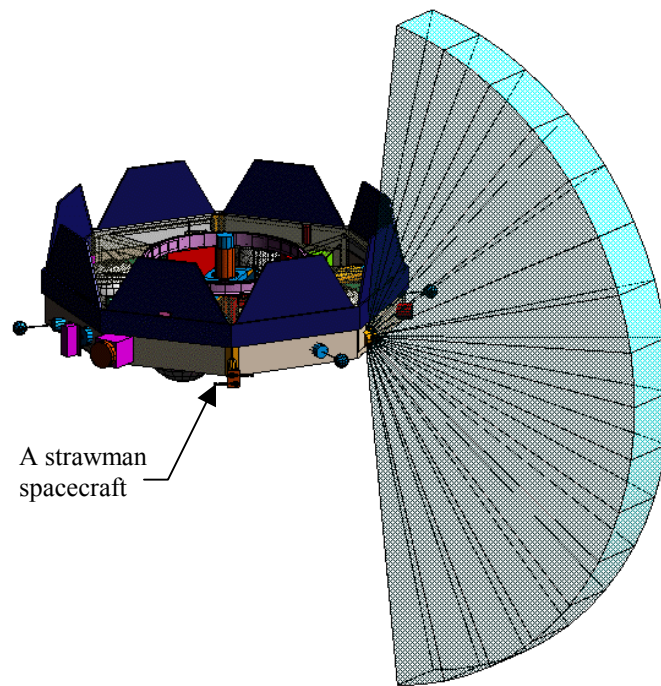


Figure 3, Energetic Particle Field of View

The energetic particle instrument measures number density, angle, energy and mass/charge for particles in the range 30keV-300keV. The instrument has a field of view of $10^\circ \times 160^\circ$ as shown in figure 3 (the spacecraft shown is for illustrative purposes and is not meant to imply a preferred spacecraft configuration.) The instrument uses the spin of the spacecraft to give almost complete coverage. There is, however, a 20° hole in the coverage around the spin axis. This instrument will require a constant high purity nitrogen purge from integration to launch. A purge port will be provided at the instrument interface. It may be assumed that the Energetic Particle Instrument has a Mil-Std-1553 or other high level interface.

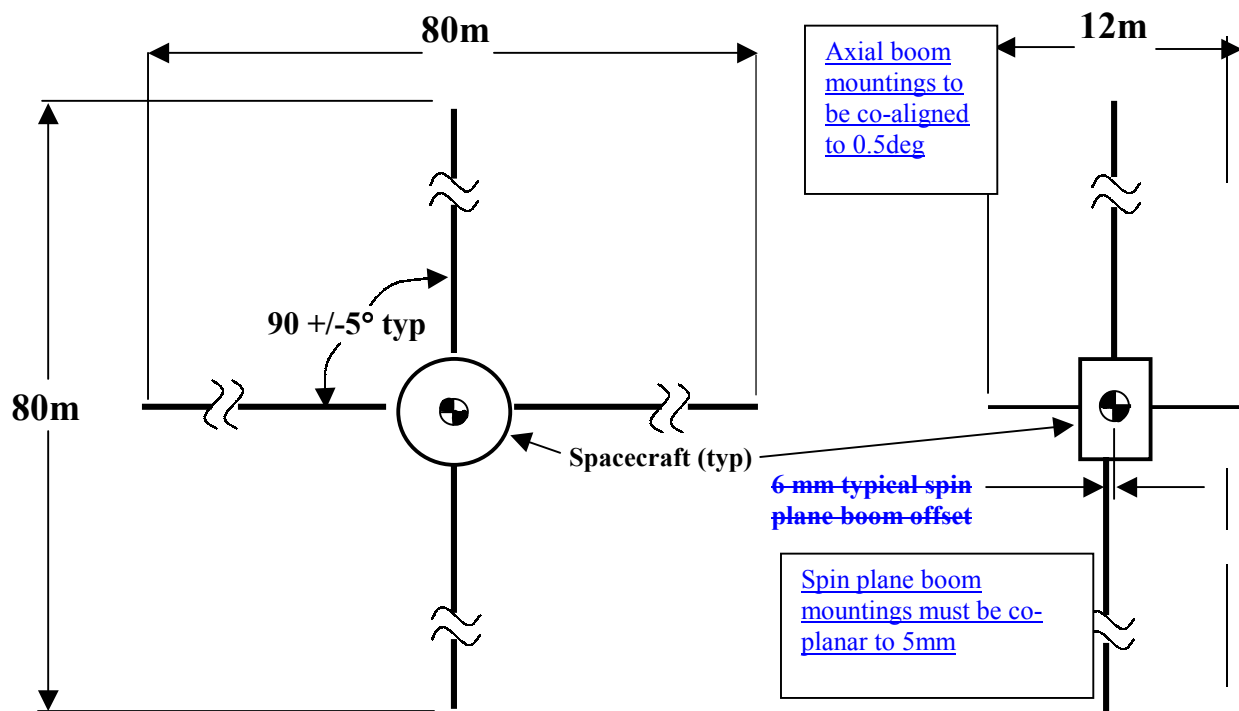


Figure 4; Electric Field Instrument

1.4 Electric Field Instrument

The electric field instrument consists of spin plane booms, axial booms and an associated electronics box.

1.4.1 The axial booms (right side of figure 4)

- Each axial boom has a 6m deployed length and less than .35 m stowed length along the deploying axis (not including the sensor sphere). Stowed volume less than 0.0075 m³.
- Capable of supporting a single 0.15 Kg mass (10 cm diameter sphere) at the tip end and a cable bundle along the entire length. The minimum (fixed base) first mode bending and torsional frequency is 1 Hz.
- Deployed boom tip precisely positioned and stable within a full cone angle of 0.2° with respect to a known reference plane while under the influence of thermal effects consistent with a low earth orbit.
- Boom and deploying mechanism must be less than 2.5kg.
- Axial booms may be packaged end-to-end or side-by-side. In either configuration, the mounting scheme must allow for the center of gravity of the deployed boom to be on the geometric spin axis.
- Mounting surfaces for the two axial booms shall be co-aligned to within 0.5°

1.4.2 The spin plane booms (left side of figure 4)

- Deployed wire boom length greater than 40 m, stowed length less than 0.35 m (not including the sensor spheres).

- Capable of supporting two 10 cm diameter sensor spheres of 0.15 Kg each along the wire length, one at 75% radially out and the other at the tip.
- Wire bundle for power and signal equivalent to 0.03 kg/m linear density
- Boom and deploying mechanism less than 2 kg
- The attachment point at the spacecraft for the booms must be at $90^\circ \pm 5^\circ$ around the circumference of the spacecraft.
- ~~- The attachment points must be in a plane and that plane must contain the spacecraft center of gravity. The center of gravity may be up to 0.6 cm out of the plane.~~
- The mounting surfaces for the spin plane booms shall be co-planar to 5mm. The spacecraft CG shall remain within 100mm axially of the boom spin plane.

1.4.3 Electronics Box

The electric field electronics box is estimated to weigh 2.5kg and be approximately 15 cm X 15 cm X 13 cm. It may be assumed that the Electric Field instrument has a Mil-Std-1553 or other high level interface.

1.5 **Magnetometer Instrument**

The magnetometer instrument consists of a sensor head and an electronics unit.

1.5.1 Spacecraft magnetic field

The spacecraft must not generate a DC magnetic field of more than 1nT at the sensor head and the spacecraft magnetic field must be known to 0.1nT DC & AC (up to 500Hz TBV). In light of these requirements it is up to the spacecraft manufacturer whether he uses a boom to mount the magnetometer head away from the main body of the spacecraft or if the magnetic cleanliness of the spacecraft is such that a boom is not necessary. The magnetometer head weighs 0.5 kg and is 31 cubic centimeters. In any event, the mass and cost of a boom will be borne by the spacecraft.

1.5.2 Magnetometer pointing accuracy

The spacecraft pointing requirements are based on the requirements of the magnetometer. The fundamental MMS pointing requirement is to be able to know the magnetometer sensor head position to 0.1° .

1.5.3 Co-alignment of Magnetometer and Electric Field booms

The alignment of the Magnetometer sensor head and the electric field booms must be known to 0.1° in the on orbit configuration.

1.5.4 Correlation of Magnetometer data and Electric Field data

The spacecraft timing system shall have sufficient resolution to allow correlation of electric field telemetry and magnetic field telemetry to less than 400 μ s. The time tag shall be applied by the C&DH system, upon receipt of data from the instrument.

1.5.5 Correlation of Magnetometers between spacecraft

The spacecraft C&DH subsystem shall allow correlation between spacecraft of magnetometer data. The IRAS shall allow relative time correlation of 400 μ s between spacecraft.

1.6 **Interspacecraft Ranging and Alarm System**

The IRAS is an RF based ranging system that works on similar principles to GPS. Each spacecraft will transmit a message in turn, and each of the other spacecraft will time-tag the receipt of the message. From the differences in the times of the received and transmitted messages an accurate measurement of the spacecraft separations can be made.

1.6.1 IRAS requirements

1. The IRAS shall measure the distance between the five Magnetospheric Multi-Scale spacecraft. The requirement is to measure the distance between the spacecraft with accuracy better than 1%.
2. A low speed serial message shall be passed from the IRAS to the spacecraft C&DH processor. The message should contain the following information: distance to other members of the formation, alarm status of each spacecraft, thruster firing status of each spacecraft, internal IRAS health and safety.
3. Maximum time from alarm message input to transmitting IRAS to alarm signal output from receiving IRAS shall be 3 sec.
4. The IRAS system shall be operational at all times in all mission modes, up to 12Re.
5. The IRAS system shall be capable of correlating time among the five spacecraft to less than 400 μ s
6. The spacecraft C&DH shall pass a message to the IRAS in the event that the spacecraft has aborted a dV maneuver.

1.6.2 IRAS to C&DH interfaces

1.6.2.1 Telemetry and Alarms

The IRAS shall have a Mil-Std-1553 interface to allow low speed telemetry and high speed alarms to pass among the spacecraft.

Table 3

Alarm	C&DH response	Comments
<u>interesting-science event</u>	Send message to all instruments within 0.5second of receipt	Other spacecraft can go into a high speed data capture mode on receipt of this alarm
One spacecraft has aborted a thruster firing	Receiving spacecraft abort thrusting	During maneuvers the five spacecraft must remain together. In the event that one of the spacecraft has to abort a maneuver, this message allows other spacecraft to abort also.

The Mil-Std-1553 schedule table shall allow for 'interesting-science event' messages to be passed from any of the instruments to the IRAS within 0.5s. The spacecraft C&DH shall pass a message to the IRAS in the event that that spacecraft has aborted a maneuver within 0.5 seconds.

1.6.2.2 Timing

The C&DH shall pass to the IRAS a discrete RS-422 timing pulse that is correlated with the fundamental timing system of the spacecraft. The pulse repetition frequency shall be 1Hz. The IRAS will use the pulses to correlate time among the spacecraft. The correlated time information shall be telemetered from the IRAS as Mil-Std-1553 messages. There is no requirement for the spacecraft to read or use the correlated time messages. The correlated time messages will be used on the ground to correlate time between the spacecraft instruments.

1.6.3 IRAS antennas

The IRAS will have two S-band antennas that are mounted to cover 4π steradian. The locations of the antennas will be negotiated between the spacecraft manufacturer and the IRAS designers.